Validation and Update of Hybrid-Empirical Ground Motion (Attenuation) Relations for CEUS

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Investigations Undertaken

The main objective of this project is to validate and update the hybrid-empirical ground motion (attenuation) relation that was developed previously by the PI (Campbell, 2002, 2003) for predicting peak ground acceleration (PGA) and response-spectral acceleration (SA) in the Central and Eastern United States (CEUS). These relations were used in the 2002 update of the USGS national seismic hazard maps (Frankel et al., 2002) as an alternative to the point-source stochastic and finite-source theoretical ground motion relations that were available at the time. The update will be done using the Hybrid Empirical Method (HEM) described by Campbell (2003).

The HEM is considered a "hybrid" method because it uses modified empirical ground-motion estimates from one area (the host region) to develop ground motion estimates for another area (the target region), which can have significantly different tectonic and seismogenic properties. These empirical estimates are modified using simple seismological models to account for the relative differences in the source, propagation, and site characteristics between the two regions.

The HEM as it will be applied in this project consists of the following seven steps:

1. Select empirical ground motion relations appropriate for estimating median values of PGA and SA and their associated aleatory standard deviations on rock in the WUS (the host region) to provide empirical estimates of ground motion for a pre-defined set of magnitudes and distances.

2. Select a set of seismological parameters and their associated uncertainty appropriate for the WUS (the host region) and the CEUS (the target region) to use with the stochastic simulation method (Boore, 2003). These parameters account for differences in the source, propagation, and site characteristics that are either known or hypothesized to exist between the two regions.

3. Use the selected seismological parameters together with the stochastic ground-motion simulation computer program SMSIM (Boore, 1996) and the finite-source stochastic ground-motion simulation computer program FINSIM (Beresnev and Atkinson, 1999), or its successor, to develop model-based ratios of PGA and SA and their associated uncertainty between the CEUS and the WUS for the same set of magnitudes and distances used to derive the empirical ground-motion estimates for the WUS.

4. Use the model-based ground-motion ratios to adjust the WUS empirical ground-motion estimates and their aleatory standard deviations to those expected in the CEUS.

5. Use the adjusted ground-motion estimates and aleatory standard deviations in the CEUS to calculate the median estimates of PGA and SA, the mean estimates of the aleatory standard deviations of PGA and SA, and their associated epistemic uncertainty for the same set of magnitudes and distances used to derive the empirical ground-motion estimates for the WUS.

6. Use the median estimates of ground motion and the mean estimates of aleatory standard deviations for the CEUS to develop ground motion relations for PGA and SA using generalized nonlinear regression analysis.

7. Use the epistemic uncertainty in median estimates of ground motion and the mean estimates of aleatory standard deviations for the CEUS to develop epistemic uncertainty relationships for PGA and SA.

The project objectives will be met by carrying-out the following proposed work items, as revised according to the recommendations of the NEHRP review panel:

a. Review the previous hybrid-empirical ground motion relations
b. Evaluate the effect of one-corner vs. two-corner point-source stochastic models
c. Re-evaluate selected seismological parameters
d. Calibrate the CEUS ground motion relation with ground-motion recordings in CEUS
e. Select more appropriate WUS empirical attenuation relations
f. Update hybrid-empirical ground motion relations
g. Develop relationships for epistemic uncertainty

Results

Limited progress has been made on the project as a result of significant delays in acquiring data needed to accomplish some of the key work items. A summary of what has been done and what problems have been encountered that have delayed the project is summarized by work item below.

Review Previous Hybrid-Empirical Ground Motion Relations

This item will be completed during production of the Final Technical Report.

Evaluate Effect of One-Corner vs. Two-Corner Point-Source Stochastic Models

This work item as originally envisioned will likely be revised based on new information. The PI attended a one-day workshop on "Attenuation of Ground Motion in the Central and Eastern United States" on August 4, 2005 in Menlo Park, California, that was jointly sponsored by the USGS and the U.S. Nuclear Regulatory Commission (NRC). In this workshop, Gail Atkinson acknowledged that the two-corner source model that she previously developed for southeastern Canada and northeastern United States (Atkinson and Mereu, 1992) and later updated using additional data (2004a, 2004b) likely results in an underestimation of SA at moderate periods. As a result, she proposed that stochastic ground-motion estimates should be based directly on finite-source stochastic models rather than on one-corner or two-corner point-source models, at least for the larger magnitudes of interest in engineering. She presented progress on developing these models for both the CEUS as well as the Western United States (WUS). These models capture the effects that the two-corner stochastic models were intended to capture, but without the bias at mid-periods. If these models are available in time, they can serve as a consistent basis for testing the impact of using two-corner source spectra instead of one-corner source spectra in the development of ground motion adjustment factors. She hoped that these new finite-source models would be available by the end 2005.

Re-evaluate Selected Seismological Parameters

At the August 2005 CEUS ground-motion workshop, The PI discussed with Gail Atkinson and Dave Boore the choice of seismological parameters to use with the stochastic method. Gail mentioned the availability of a revised stochastic two-corner ground motion model for the CEUS (Atkinson, 2004a, 2004b), which she recommended using in my update, with the caveat that it might underestimate SA at mid-periods. We also discussed whether the one-corner stochastic model of Raoof et al. (1999) should be used for the WUS or whether a recently developed procedure by Scherbaum et al. (2006) should be used to derived seismological parameters directly from the empirical ground motion relations. She thought that this latter approach should be considered, although because of limitations in the empirical relations, both she and Dave thought that some of the parameters (e.g., anelastic attenuation) might need to be constrained based on the results of Raoof et al.(1999).

Calibrate CEUS Ground Motion Relation with Ground-Motion Recordings in CEUS

No progress has been made on this work item. It will be done during development of the CEUS ground motion relations.

Select More Appropriate WUS Empirical Attenuation Relations

The intent of this work item was to use the new WUS empirical ground motion relations that are currently being developed under the PEER Lifelines *Next Generation Attenuation (NGA)*

Project. The NGA project was to be completed at the end of 2004, but problems related to the development and verification of the NGA database, difficulties in evaluating new parameters and functional forms, and outside review by the USGS has delayed the completion of the project to the end of 2005. As a result, it has not been possible to use these new relations. It is critical that these new NGA relations be used in the updated hybrid-empirical ground motion relation, because it is highly likely that they will be adopted for use in the 2008 update of the national seismic hazard maps (M.D. Petersen, personal communication). One of the criticisms of the previous hybrid-empirical ground motion relation was that the empirical ground motion relations used to estimate PGA and SA in the host region (WUS) were not the same as those used by the USGS to estimates ground motions for this same region.

Update Hybrid-Empirical Ground Motion Relations

No progress has been made on this work item.

Develop Relationships for Epistemic Uncertainty

No progress has been made on this work item.

Non-technical Summary

The objectives of this project are to validate and update the hybrid-empirical ground motion (attenuation) relations that were developed previously by the PI for the Central and Eastern United States (CEUS). Because of delays in acquiring critical data, a request has been submitted to extend the one-year project through the first quarter of 2006. Nonetheless, some progress was made on several of the work items, including: (1) attending a CEUS ground-motion workshop sponsored by the USGS and NRC, (2) discussing new data and methodologies with Gail Atkinson and Dave Boore, and (3) learning of Gail Atkinson's proposal to replace the two-corner point-source stochastic model with a finite-source stochastic model.

Reports Published

No reports have been published to date.

Availability of Seismic, Geodetic, or Processed Data

No seismic, geodetic, or processed data have been generated to date.

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